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Title: Agroforestry in Europe: a land management policy tool to combat climate change

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Abstract

Agroforestry is an integrated land use management that combines a woody component with a lower story agricultural production recognized as one of the most important tools to mitigate and adapt to climate change. The objective of this paper is to provide a categorization and extent of agroforestry practices linked to agricultural and forest lands at regional level and evaluate how are they promoted by the previous (2007-2013) and current CAP (2014-2020) with a special focus on climate change mitigation potential. Agroforestry occupies almost 20 million hectares in Europe, being silvopasture and homegardens the most extensively spread practices and forest farming not quantified. Agroforestry practices are promoted at European level but in a really complex form as more than 25 measures are implemented to enhance the existing 5 agroforestry practices (silvopasture, silvoarable, riparian buffer strips, forest farming and homegardens). Simplification of the number of measures to promote agroforestry practices is needed to better follow up the implementation and to evaluate and provide future policies more adapted at European levels. Huge potential climate change mitigation options should be focused on the use of silvopasture on forest lands to reduce forest fires and to increase the presence of the woody component on arable lands (silvoarable) but also on the promotion of forest farming and homegardens as forms to increase the use of short supply chains and to increase the connection of urban, periurban and rural areas within a bioeconomy and circular economy framework.

Keywords: silvopasture, silvoarable, homegardens, riparian buffer strips, forest farming

1 Introduction

Agroforestry understood as the deliberate integration of a woody component with a lower story agricultural production is been highlighted by the FAO (Buttould, 2013) as one of the most powerful tools to mitigate and adapt to climate change all over the world. However, in spite of being quite extensively used in tropical countries, the extent of agroforestry in temperate areas is rather small as happens in Europe (Herder et al. 2009) or the USA (USDA 2011, 2013) due to the previous intensification of farming systems, as well as the lack of integration of forest and agricultural land and the absence of current adequate policies to promote agroforestry practices.

Agroforestry is a land use option associated to different land use covers such as those linked to forestry and agriculture (grasslands, arable lands and permanent crops) on which intensive farming has been promoted by the European Common Agrarian Policy (CAP) during the last century as happened for example in Germany (Niedertscheider et al. 2014). Intensification has caused an improvement of production based on the use of external inputs and losses of soil fertility but also created many environmental concerns and mostly soil degradation (Tsiafouli et al. 2015). On the contrary, agroforestry thanks to the woody component brings to the system an improvement of the use of the existing resources both at aerial and belowground level, linked the so called ecointensification. At aerial level, the increase of the photosynthetically active biomass (crop/pasture leaves + tree leaves) per hectare causes a better use of the sun radiation that can originate between the 20 and 80% more biomass production (Dupraz and Liagre 2011). This increase of the biomass production can be associated with an improvement of the farmer productivity if adequate species are mixed, and at the same time increases the source of organic matter into the soil, the main reservoir (81%) of C in terrestrial ecosystems (Karsenty et al. 2003), therefore contributing to mitigate climate change.

The heterogeneity caused by the presence of the woody component in agricultural lands creates patches that improves alpha biodiversity, but also originates modifications at landscape level therefore improving beta and gamma biodiversity. Adequate biodiversity management at landscape level is also a powerful tool to improve biomass productivity (Gross 2016). At belowground level, the different depths of woody and herbaceous plant roots improve the re-utilization of the nutrients enhancing internal nutrient recycling and avoiding nutrient losses that causes many environmental concerns (Rigueiro et al. 2009).

The European CAP is one of the main drivers of the agricultural and forestry land use in Europe. Nevertheless it does not consider in depth the role that agroforestry has to play. A better approach aiming at agroforestry research feeding future CAP programs is needed (McNie et al. 2016) to provide more agricultural and forest sustainable systems. Former CAP has modified the way of farming in Europe, without supporting the preservation of the woody component in agricultural lands in its origins and brought negative impacts on environment. Moreover, CAP increased the amount of forest lands in Europe but without linking them to agricultural production. On one hand, CAP reduced the sustainability of agricultural lands and, on the other hand, CAP is not keen on fostering the agricultural use of afforested or reforested areas that are usually poorly managed as forest practices such as pruning or thinning are not usually carried out. The underuse of forest lands causes a reduction of the returns from these areas. In both types of land cover, agroforestry can be an extraordinary tool to improve sustainability and land use to deliver forest and agricultural products, which may be linked to the stabilization of rural population in Europe, one of the main social problems in European rural areas. Agroforestry can also be implemented in urban, periurban and rural areas when associated to homegardens. Homegardens are key to provide local and more

sustainable healthy food reducing impact of agricultural activities on climate change (i.e. Slowfood movement or Km 0 strategy).

Fostering agroforestry in Europe through the CAP should be linked to the knowledge of the extent of agroforestry practices operating at plot level, the main scale on which CAP acts, but also considering national and regional level, as CAP is currently deployed in 118 different Rural Development programs at European level. In this regard, den Herder et al. (2017) made the first serious attempt to categorize the extent of agroforestry per country in Europe based on the use of LUCAS (Land Use/Cover Area frame Survey) and considering the previous definition of agroforestry in the CAP 2007-2013 framework (land use systems in which trees are grown in combination with agriculture on the same land) but not the new definition coming from the deployment of the Measure 8.2 of the Regulation 1305/2017 which defines agroforestry as a land use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same parcel of land management unit. The objective of this paper is to provide a categorization and extent of agroforestry practices linked to agricultural and forest lands at RDP-regional level and evaluate how are they promoted by the previous (2007-2013) and current CAP (2014-2020), with a special focus on climate change mitigation potential.

2 Methodology

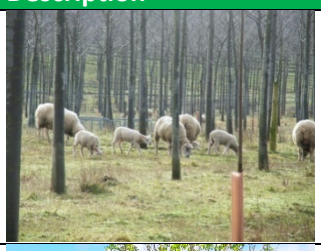
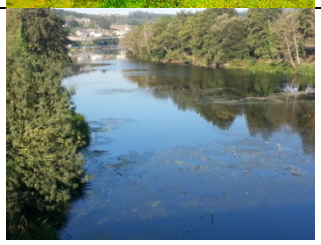
Agroforestry practices are the form on which the woody component is combined with the lower storey crop at plot level. The agroforestry practices evaluated in this paper are those described in Table 1, which are comparable to those described by some temperate countries such as the United States (USDA 2011 and 2013) or Canada and Mexico as described the Agroforestry Temperate Association (AFTA 2017). From those practices,

145 silvopasture and silvoarable are the main agroforestry practices. However, practices
146 such as homegardens and forest farming are considered for political reasons as there is a
147 clear division between forest, urban and agricultural lands from a political funding point
148 of view. Riparian buffer strips are also considered as another practice because of the
149 importance of protecting continental waters and provision of environment benefits. For
150 all of them we used “The Land Use/Cover Area frame Survey”, abbreviated as LUCAS.
151 LUCAS is a European field survey program funded and executed by EUROSTAT. Its
152 objective is to set up area frame surveys for the provision of coherent and harmonised
153 statistics on land use and land cover in the European Union (EU). LUCAS includes data
154 relative to landscape features included linear elements and isolates trees (EUROSTAT
155 2013). EUROSTAT has the LUCAS survey micro-data collection of cover and land
156 uses which is freely available on the LUCAS website (EUROSTAT 2013). LUCAS
157 survey has been carried out in 2009, 2012, and 2015. In this paper, we analysed the
158 2012 data, the year before that Croatia became the 28th EU member state, so the results
159 are only referred to the EU27.
160 LUCAS is a two-phase sample survey. The first phase is a systematic sample with
161 points spaced 2 km apart in the four cardinal directions covering the whole of the EU’s
162 territory (around 1.1 million different points). Each point of the first phase sample was
163 photo-interpreted and assigned to one of the following seven predefined land cover
164 strata: arable land, permanent crops, grassland, wooded areas and shrubland, bareland,
165 artificial lands, and water bodies.
166 In a second phase, a representative subset of 270,267 points was selected for the new
167 field survey, based on the stratified information produced by a quasi-regular grid with a
168 LUCAS sampling point on each 4-km block on average. However, points placed above
169 1,500 m and away from the road network were considered inaccessible and therefore

were not included. The 270,267 points selected for the second phase were visited in situ by the field inspectors in 2012.

LUCAS uses a double classification system for land covers with multiple layers, used only for specific landscapes, such as agroforestry and complex or heterogeneous area. For example, in agroforestry practices a woody vegetation layer is typically accompanied by a secondary layer composed of crops or grass. In such cases, LUCAS would enter the woody component (trees or shrubs) as the primary land cover (LC1) and crops, grass or bare soil as the secondary land cover (LC2) (see EUROSTAT 2013 for more information). Another useful variable included in the LUCAS database is land management, which contains information if there are signs of grazing. By identifying certain combinations of primary and secondary land cover and land management it is possible to identify agroforestry points and stratify them into different agroforestry practices. To identify arable agroforestry systems the combinations of LC1 and LC2 must indicate intercropped permanent crops, woodlands or scrubland.

184 Table 1. Spatial agroforestry practices in Europe (Modified from Association for
185 Temperate Agroforestry (AFTA 1997; Alavapati and Nair 2001; Nair 1994, Alavapati
186 et al. 2004; Mosquera-Losada et al. 2009).

Agroforestry practice	Description	
Silvopasture		Combining woody with forage and animal production. It comprises forest or woodland grazing and pastoral land with hedgerows, isolated/scattered trees or trees in lines or belts
Homegardens or kitchen gardens		Combining trees/shrubs with vegetable production in urban areas, also known as part of "trees outside the forest" and arable land with hedgerows, isolated/scattered trees or trees in lines or belts
Riparian buffer strips		Strips of perennial vegetation (trees/shrubs) natural or planted between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality. They can be combined with arable lands (silvoarable) or grasslands (silvopasture) but are signified by its role in preserving water streams
Silvoarable		Widely spaced woody vegetation inter-cropped with annual or perennial crops. Also known as alley cropping. Trees/shrubs can be distributed following an alley cropping, isolated/scattered trees, hedges and line belts design
Forest farming		Forested areas used for production or harvest of natural standing speciality crops for medicinal, ornamental or culinary uses, including those integrating forest and agricultural lands

187

188 The agroforestry practices identification was based on the combination of two land
189 covers which integrates a woody component (LC1) and an agricultural activity. The
190 agricultural activity can be identified by the presence of crops (LC2) to quantify
191 silvoarable or grassland as secondary cover (LC2) and the column "land management"

192 pointing out signs of grazing to determine the area of silvopasture (Table 2). The
193 presence of homegardens was marked by the land use fields (LU1 and LU2). To
194 estimate the extent of agroforestry of silvoarable, silvopasture and homegardens in
195 hectares with the aim to describe the agroforestry practices at RDP region level, we
196 divided the number of points coded as agroforestry in each territory by the total number
197 of LUCAS points in this territory and multiplied this by the surface of the territory.
198
199

200 Table 2. Criteria used for identifying the agroforestry practices. (d.: dominated).

Land cover / variable	Code	LUCAS class	Arable AGF	Silvopast AGF	All AGF
Cereals	B11	Common wheat	LC2		LC2
	B12	Durum wheat	LC2		LC2
	B13	Barley	LC2		LC2
	B14	Rye	LC2		LC2
	B15	Oats	LC2		LC2
	B16	Maize	LC2		LC2
	B17	Rice	-		-
	B18	Triticale	LC2		LC2
	B19	Other cereals	LC2		LC2
Root crops	B21	Potatoes	LC2		LC2
	B22	Sugar beet	-		-
	B23	Other root crops	LC2		LC2
Non- permanent industrial crops	B31	Sunflower	LC2		LC2
	B32	Rape and turnip rape	-		-
	B33	Soya	-		-
	B34	Cotton	-		-
	B35	Other fibre and oleaginous crops	LC2		LC2
	B36	Tobacco	LC2		LC2
	B37	Other non- permanent industrial crops	-		-
Dry pulses, vegetables and flowers	B41	Dry pulses	LC2		LC2
	B42	Tomatoes	LC2		LC2
	B43	Other fresh vegetables	LC2		LC2
	B44	Floriculture and ornamental plants	LC2		LC2
	B45	Strawberries	LC2		LC2
Fodder crops	B51	Clovers	LC2		LC2
	B52	Lucern	LC2		LC2
	B53	Other leguminous and mixtures for fodder	LC2		LC2
	B54	Mix of cereals	LC2		LC2
Grassland	E10	Grassland with sparse tree/shrub cover		LC2	LC2
	E20	Grassland without tree/shrub cover		LC2	LC2
	E30	Spontaneously re-vegetated surfaces		LC2	LC2

Land cover / variable	Code	LUCAS class	Arable AGF	Silvopast AGF	Homegarden	All AGF
Permanent crops: fruit trees	B71	Apple	LC1	LC1		LC1
	B72	Pear	LC1	LC1		LC1
	B73	Cherry	LC1	LC1		LC1
	B74	Nut trees	LC1	LC1		LC1
	B75	Other fruit trees and berries	LC1	LC1		LC1
	B76	Oranges	LC1	LC1		LC1
	B77	Other citrus fruit	LC1	LC1		LC1
Other Permanent crops	B81	Olive groves	LC1	LC1		LC1
	B82	Vineyards	LC1/LC2	LC1		LC1/LC2
Permanent industrial crops	B84k	Mulberries and carob	LC1	LC1		LC1
	B84m	Willow	-	LC1		LC1
Woodland	C10	Broadleaved woodland	LC1	LC1		LC1
	C21	Spruce dominated woodland	-	LC1		LC1
	C22	Pine dominated woodland	LC1	LC1		LC1
	C23	Other coniferous woodland	LC1	LC1		LC1
	C31	Spruce dominated mixed woodland	-	LC1		LC1
	C32	Pine dominated mixed woodland	LC1	LC1		LC1
	C33	Other mixed woodland	-	LC1		LC1
Shrubland	D10	Shrubland with sparse tree cover	LC1	LC1		LC1
	D20	Shrubland without tree cover	LC1	LC1		LC1
Grassland	E10	Grassland with sparse tree cover		LC1		LC1
Land management	1	Signs of grazing		Yes		Yes
Homegarden	U113	Kitchen garden			LU1+LU2	LU1+LU2

LC1 = Primary land cover

LC2 = Secondary land cover

LU1 = Primary land use

LU2 = Secondary land use

- = The variable was included in the analysis but there were no observations where occurred

A different approach was used to categorize hedgerows and riparian buffer strips. The quantification of hedgerows and riparian buffer strips (avenue trees, conifer strips, managed and unmanaged hedgerows close or not to inner waters) was based on the 270,267 points visited by surveyors who took note of the features that touched the 250 m transects coming from each of the 270,267 points. The different features were identified in each transect. In addition, the length occupied by the different characteristics of these points were measured in 1283 transects, allowing at some extent to quantify how many meters are occupied by a particular feature identified as LFLM (landscape features mean length). Estimating the hectares occupied by each landscape feature was based on the counting of the number of times that a feature appears in each specific transect that was multiplied by LFML. The result was summed up for all transects of 250 m at a regional level and divided by the total number of transects, therefore obtaining the percentage of a specific landscape feature length in each transect. To determine riparian buffer strips, those hedgerows close to running waters or water bodies were extracted from the hedgerows database and processed. The percentage of a feature per transect was multiplied by the total surface of each region to provide an indicator of the number of hectares that each landscape feature occupies that may be also used in the future in order to estimate the evolution of the landscape features among LUCAS surveys.

It is important to highlight that the number of hectares given for each agroforestry practice category is an absolute value useful to quantify their evolution in the successive LUCAS surveys. Moreover, due to the sampling form carried out in LUCAS, data from silvopasture, silvoarable and homegardens (obtained by survey points) cannot be combined with riparian buffer strips and hedgerows (obtained by transect points), as the later ones are included in the previous ones.

Forest farming was not evaluated in the LUCAS surveys, so we present a summary of a review carried out by the 2015 Ministerial Conference on the Protection of Forests in Europe about the status of the production of forest farming (non-wood forest production).

Policy analysis

The CAP is divided in Pillar I (EU 2013b) and Pillar II (EU 2013a). Pillar I pays areas within the arable, permanent grassland and permanent crops land cover when some requirements are fulfilled, while Pillar II is more related with the environment and based on a set of measures selected and developed by Member States and their regions to be adapted to the socioeconomic and environment conditions of the farms (Vanschoenwinkel et al 2016). A policy analysis evaluating the promotion of agroforestry practices was carried out in the deployment of the 88 and 118 Rural Development Programs of the periods 2007-2013 and 2014-2020 available in October 2016 in internet, considering the CAP wording linked to the different agroforestry practices shown in Table 3.

Table 3. Agroforestry practices can be linked to dominant land use categories (agriculture, forest or peri-urban).

Land use and agroforestry practice		Examples	Brief description
AGRICULTURE	Silvopasture	Wood pasture and parkland	Typically areas used for forage and animal production that includes widely-spaced non-agricultural trees and shrubs.
		Meadow orchards	Typically areas of widely-spaced agricultural trees and shrubs (e.g. fruit orchards, olive groves, vineyards) which are grazed.
	Riparian buffer strips	Hedgerows, windbreaks and riparian buffer strips, forest strips	Here the woody components are planted to provide shelter, shade, or parcel demarcation to a crop and/or livestock production system. Riparian buffer strips are typically created to protect water quality and can be linked to silvopasture or silvoarable.
	Silvoarable	Alley-cropping systems, isolated trees in arable lands	Widely spaced woody perennials inter-cropped with annual or perennial crops. As the tree canopy develops, the crops may be replaced with a grass understorey.
FOREST	Silvopasture	Forest grazing, mountain pastoralism, isolated trees in grasslands	Although the land cover is described as forest, the understory is grazed
	Forest farming	Forest farming	Forested areas used for production or harvest of naturally standing specialty crops for medicinal, ornamental or culinary uses but also apiculture
RURAL, URBAN AND PERIURBAN	Homegardens	Homegardens	Combining trees/shrubs with vegetable production usually associated with peri-urban or urban areas

Upscaling

The obtained geographical indicators from LUCAS (percentage and number of hectares) as well as the policy indicators (number of measures promoting the introduction or maintenance isolated trees and hedgerows) were up-scaled and mapped per region of Europe by using QGIS 2.18.

3 Results

In Europe, total agroforestry practices including silvopasture, silvoarable and homegarden practices are calculated to occupy 19.77 million hectares (Figure 1, Table 4). Silvopasture practice represents over 17.77 million hectares in Europe (4.1% of EU territory). About 90% of the 19.77 million agroforestry hectares is linked to silvopasture practices (including 4.3% where permanent crops or fruit trees are the woody component) (Figure 1). The area occupied by silvopastoral systems with fruit trees (termed multipurpose silvopasture in Figure 1) is around 850,000 ha. The second greatest area of agroforestry comprises homegardens representing 8.35% of all land occupied by agroforestry practices in Europe (1.63 million hectares). Silvoarable practices (the combination of an arable crops with a woody component) is only placed in 360,000 hectares representing less than 1% of the EU land occupied by agroforestry practices, over half of it managed under permanent crops (referred to as "multipurpose silvoarable" in Figure 1). Riparian buffer strips and hedgerows cover 1.8 million hectares considering the coverage that their canopies have. On the contrary, no data are available for forest farming.

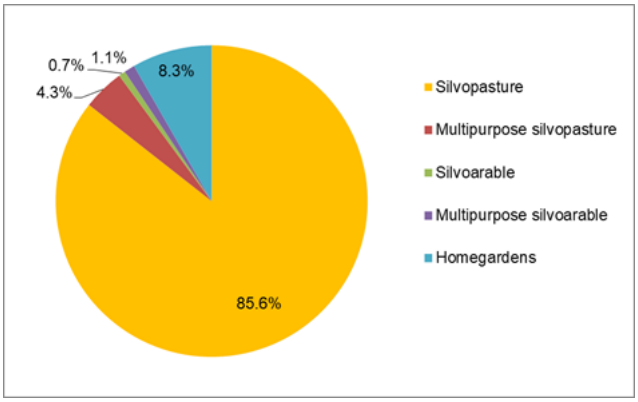


Figure 1. Proportion of agroforestry land in the EU allocated to different agroforestry practices. Multipurpose silvopasture is a type of silvopasture on which the woody component is a fruit trees. Multipurpose silvoarable is a type of silvoarable on which the woody component is a fruit trees.

Table 4. Area (Mha: Million hectares) of grazed and ungrazed silvopasture areas across the EU27 as defined by LUCAS land cover types (Source, LUCAS 2012). Proportion of land cover with respect to the total territory of Europe and to the potential area that could theoretically be grazed within each woody vegetation category (potential of land to be used as silvopasture) expressed as percentage and percentage within the European Union land (EU). PLtbU: “potential land to be used as” silvoarable or silvopasture.

Land cover	Grazed (Mha)	Not grazed (Mha)	Total (Mha)	PLtbU silvopasture (%)	EU (%)
Silvopasture	17.775	98.803	116.578	83,97	0.68
Land cover	Silvoarable (Mha)	Non-silvoarable (Mha)	Total (Mha)	PLtbU silvoarable (%)	EU (%)
Total	0.360	93.235	93.59	99.62	0.07

3.1 Silvopasture

Silvopasture and multipurpose trees silvopasture are present on around 12% of the grassland area in Europe (Table 4). However there remains a large potential for future increase. The majority of silvopasture is located in the southern countries of Europe (Figure 2), but this practice also covers many hectares in northern countries due to the size of the country but low percentage, while the contrary happens in some regions of Italy.

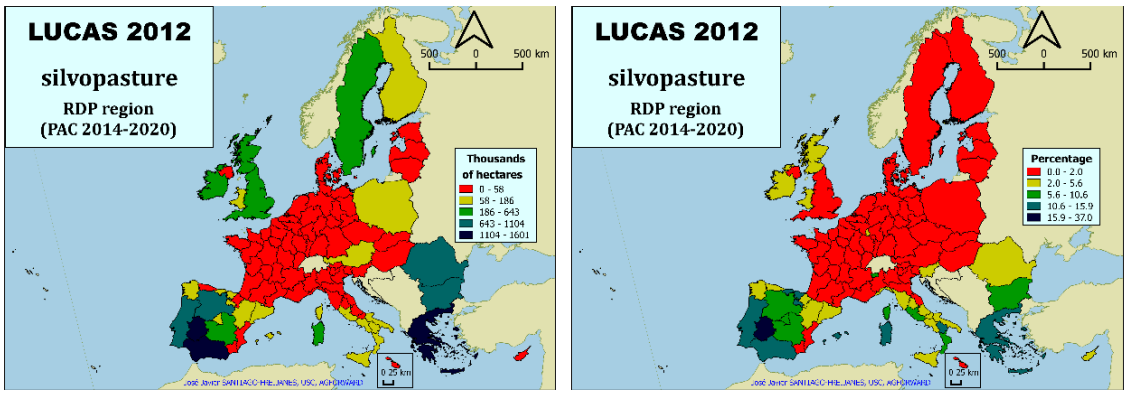


Figure 2. Area (left) and proportion (right) of European land use associated with all silvopasture, woodland silvopasture, shrubland silvopasture, and silvopasture with multi-purpose trees

3.2 Homegardens

Homegardens comprise the multilayer vegetation that surrounds households that supply fruits but also vegetables to owners. The proportion of land allocated to homegardens is highest in Eastern Europe (e.g. the Czech Republic, Slovakia, Romania) and lowest in countries placed in Central and Northern Europe. Some Atlantic regions such as England, Asturias and Galicia have some proportion of homegardens. Most of the Spanish regions have a higher number of hectares of homegardens in spite of the low proportion due to the large size of these regions (Figure 3).

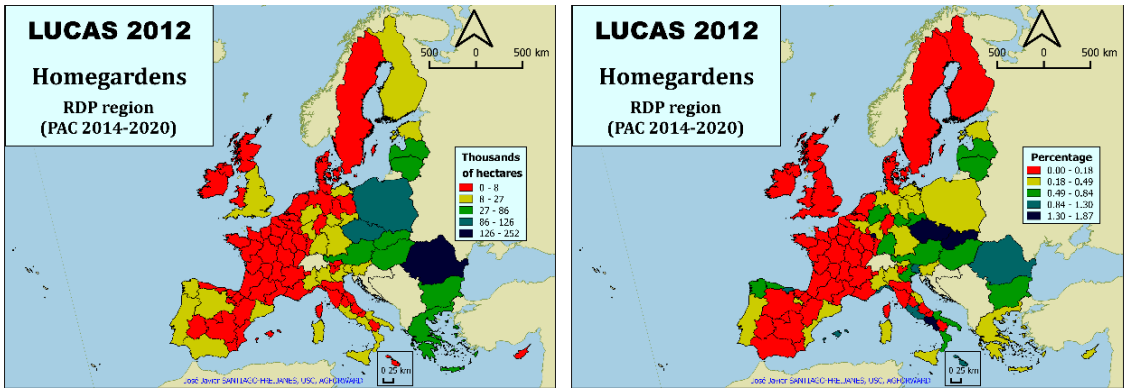


Figure 3. Area (left) and proportion (right) of European land use associated with homegardens

3.3 Silvoarable

Silvoarable practices include the woody component distributed in different forms (borders, hedgerows, windbreaks, scattered trees, lines) deliberately integrated with cropland. Silvoarable practices were also estimated by those annual crops intercropped among permanent crops (fruit trees), shrublands with and without sparse tree cover and woodlands. The total area occupied by silvoarable practices in Europe, using the LUCAS (2012) database, is around 360 thousand hectares (Table 4), representing less than 0.08% of total European area. By contrast the area that could be potentially used in silvoarable systems is large (99.62%). Figure 4 describes the proportion and the number of hectares occupied with different silvoarable practices in Europe. The greatest proportional allocation of land to silvoarable practices occurs in southern countries such as Spain, Portugal and Italy.

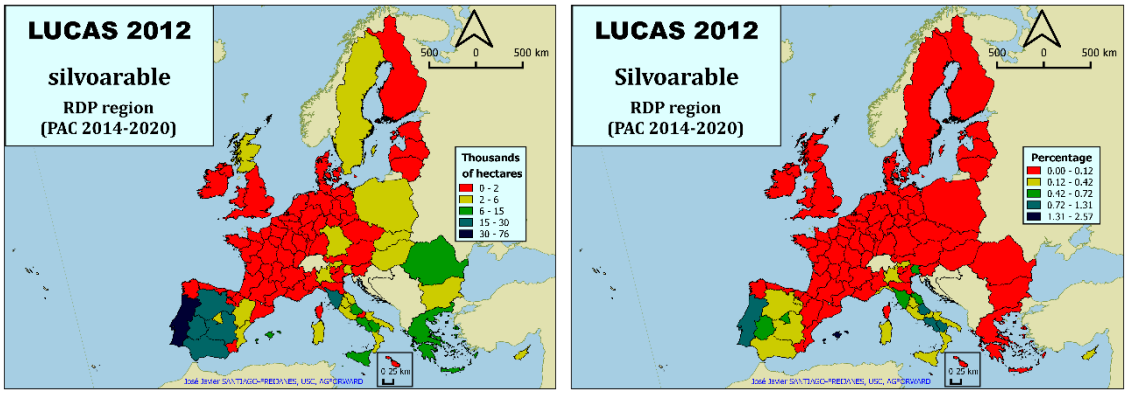


Figure 4. Silvoarable practices linked to permanent crops (top), woodland (medium) and shrubland with sparse tree cover expressed as percentage (left) and hectares (right) per region in Europe

3.4 Riparian buffer strips

The total area of hedgerows in Europe that can be considered as part of silvopasture or silvoarable practices is around 1.78 million hectares representing about 0.42% of the territorial area of the EU. The largest areas of hedgerows are found in France, the UK, and Italy, with a high proportional area in Ireland but also a high number of hectares of hedgerows can be found in Romania, Bulgaria, Poland and Hungary (Figure 5). From them, riparian buffer strips amount 362 thousand hectares in Europe representing less than 0.08% of the total land of EU27 (Figure 5). This type of agroforestry practice can be divided into two subtypes: riparian buffer strips linked to inland water bodies (running waters and lakes). These two groups occupy 262 and 100 thousand hectares in Europe, respectively. Out of the subgroups linked to this type of agroforestry practice (avenue trees, conifer strips, managed and unmanaged hedgerows close to inner waters), there were larger proportions with avenue trees than with unmanaged and managed hedges or conifer strips.

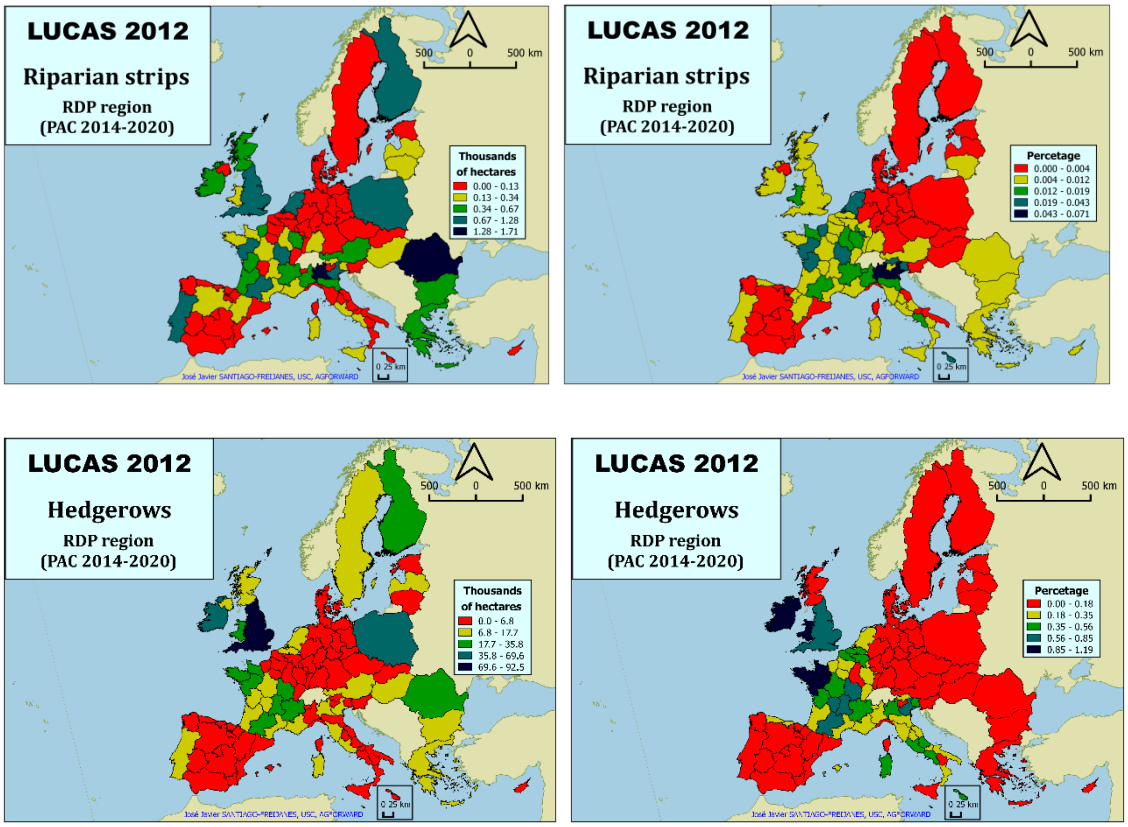
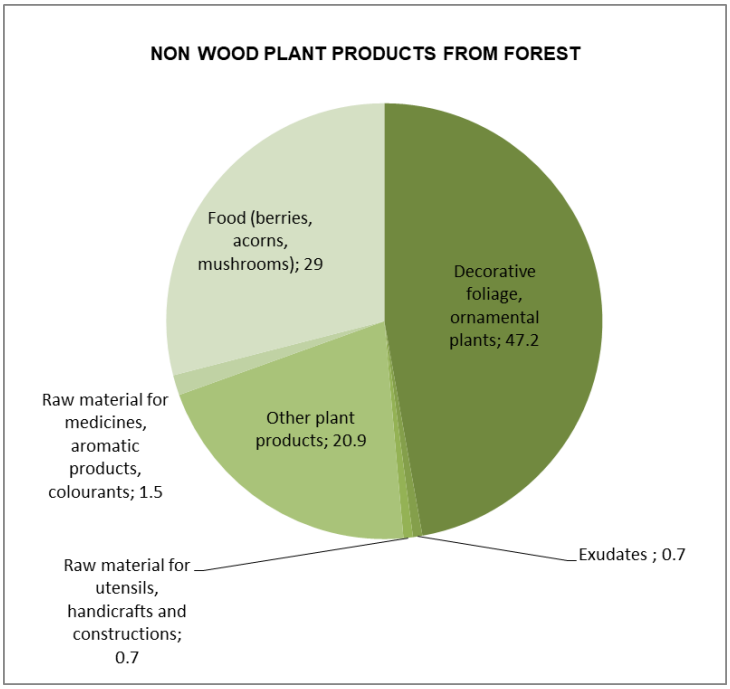


Figure 5. Area (left) and proportion (right) of European land use associated with riparian buffer strips (top) and hedgerows (bottom).

3.5 Forest farming

There are no official European statistics linked to the territorial use of forest farming, in spite of the importance of this sector supplying goods and services. FAO summarized the economic value of non-wood forest products (NWFPs) (FAO 2005), but they do not link it to the area of forest that is currently used for non-wood forest products. In the 2015 Ministerial Conference on the Protection of Forests in Europe, the total value of marketed NWFPs was calculated to be 2,300 million Euros, mainly comprising plant products (1,680 million Euros) and animal products (620 million Euros). However, this is not easy to quantify. The distribution and activities of non-wood area where forest products are produced in Europe is not known. Quantitative data related to markets are

347 only available for 27 countries, which provide only information about some of the
348 marketed plant products or raw materials coming from forest farming (Figure 6).



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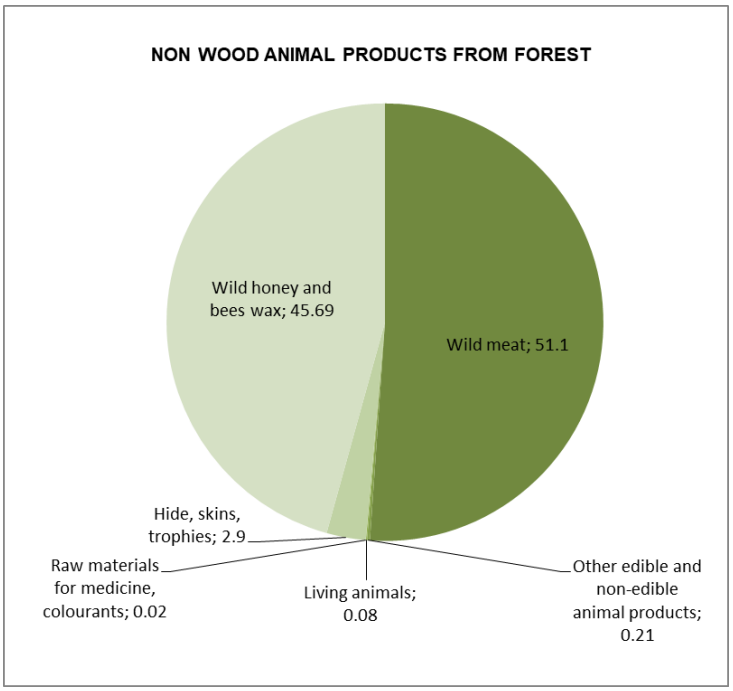

350

351 Figure 6. Percentage of profitability obtained by plant (above) and animal (below)
352 products as non-wood products from forests (Ministerial Conference on the Protection
353 of Forests in Europe 2015a)

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3.6 Policy

The promotion of agroforestry practices and the relationship to agricultural wording across Europe can be seen in Table 3. Some of them are promoted by the CAP as can be seen for the 88 and 118 Rural Development Programs of 2007-2013 and 2014-2020 period in Tables 5 and 6, respectively. During the period 2007-2013 there were 26 different measures promoting agroforestry (Table 5), while this number reached the value of 27 within the period 2014-2020 (Table 6). The same activity within an agroforestry practice can be enhanced by different measures (avoiding double founding) depending on the Rural Development Programs, with hedgerows being promoted by 12 out of 2 (50%) and 18 out of 27 (70%) measures within the 2007-2013 and 2014-2020 Rural Development Programs, respectively. In both periods, agricultural lands were affected by almost 70% of the measures, being the 30% mainly linked to forest lands. Hedgerows creation and maintenance was the most extensively promoted activity (around 40%) to include and preserve the woody component in agricultural lands, while meadow orchards were promoted only by the 20% of the measures, in spite of being the first not eligible and the second one eligible for Pillar I payments. In both periods, the measure more extensively used to preserve or include the woody component in agricultural lands or agricultural activities in forest lands was the so called “agri-environment measure” named as 214 (30% of the whole RDPs) and 10.1 (40% of the whole RDPs) within the CAP 2007-2013 and 2014-2020, respectively, followed by the 216 (Support for non-productive investments; 16%) and 4.4 (Support for non-productive investments linked to the achievement of agri-environment-climate; 18%), within the same respectively CAPs.

378 Table 5. Number of regional programs that supported different agroforestry measure activities within the CAP 2007-2013

Agroforestry measure/actitvity		Axis 1										Axis 2												Axis 3			Axis 4	Total
		111	112	114	121	122	123	125	126	132	133	211	212	213	214	215	216	221	222	223	225	226	227	311	322	323	412	
AGRICULTURAL LAND	Meadow orchards				1										42		5									4		52
	Forest strips								1						22	2	17	2	2	1			1			4		52
	Hedgerows				2	1								3	39		30	2	2				4	1	1	13	1	99
	Isolated trees														20		12						3			4		39
FOREST LAND	Forest grazing														19		3				5	3	2			1		33
	Forest farming (apiculture)	2	1	1	16	2	3			1	1				17	1	1									1		47
	Forest farming (not apiculture)				4	7	6											2	2	2			1					24
	Mountain pastoral ism	1				2		3				1	1	1	15	2	2				1	2	1			5		37
	Total	2	1	1	22	10	9	0	1	1	1	0	0	3	117	3	63	6	6	3	5	3	11	1	1	23	1	383

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380

381 Table 6. Number of regional programs that supported different agroforestry measure activities within the CAP 2014-2020.

	Agroforestry measure/actitity	1.1	1.2	2.1	2.3	4.1	4.2	4.3	4.4	5.1	6.1	6.3	7.4	7.6	8.1	8.2	8.3	8.4	8.5	8.6	9.1	10.1	11.1	11.2	12.1	13.2	15.1	16.5	Total
AGRICULTURAL LAND	Meadow orchards					3		2	6					3								52	1						67
	Forest strips								20				1	7		1			5	1		34			1	1	2	1	74
	Hedgerows	1	1	1	1			1	42	1			1	7		2	1		3			53	1	1	3	1		1	122
	Isolated trees								16					5					1			33			4	1		1	61
FOREST LAND	Forest grazing							2							1	3		1	2			14							23
	Forest farming (apiculure)		1	1		6	2				2	1			1					5		34	8	6					67
	Forest farming (not apiculture)		1	1		1	1		1											12	1								18
	Mountain pastoralism					3		6	4					4								17	1						35
	Total	1	3	3	1	10	3	9	83	1	2	1	2	23	2	6	1	1	11	18	1	185	10	7	8	3	2	3	467

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4 Discussion

In Europe, total agroforestry practices occupy 19.77 million hectares. This is equivalent to the area of 15.4 million hectares reported by den Herder et al. (2016) but it also includes 2.66 million hectares of grazed shrubland following the current CAP agroforestry definition and 1.8 million hectares of homegardens. About 90% of the 19.77 million hectares is linked to silvopasture practices mostly associated to southern countries of Europe as their livestock sectors (goats, sheep but also autochthonous breeds able to be grown up in environments with summer droughts) are supported by the capacity of woody vegetation to provide feed during the dry summer time and to extend the growing season thanks to the shade they provide to the lower story in extreme hot events (Etienne 1996, Papanastasis et al. 1999; Castro et al. 2009). Silvopasture and fruit trees silvopasture are present on almost 10% of the grassland areas of Europe, which is ten times more than that declared by the USA for the silvopasture practice in the USA (USDA 2013); however there remains for large potential for future increase in Europe. CAP Pillar I was reluctant to identify this silvopasture practices as fully eligible as only herbaceous vegetation was recognized as agriculture in the previous CAP. However, since CAP 2014-2020 the presence of woody component can be included as part of the land to claim the full payment if associated to Established Local Practices. Moreover, in the recent ONMIBUS regulation proposal (Council of European Union 2017) that entered into force last January 2018, countries will not have to declare silvopasture lands as part of the Established Local Practices (EU 2013b, Regulation 1307/2013) to allow farmers to be paid by the Pillar I funds when predominant woody vegetation is present in permanent grasslands. This modification is extremely important as silvopasture including woody vegetation is key to mitigate climate change due to the carbon that the woody

410 component sequesters as found in mountain areas were water bodies' reserves provide
411 clean water to the 50% of the world population (Dixon et al 1994; Kapos et al. 2000,
412 Djukic et al. 2010; Ward et al. 2014). In addition, silvopasture practices are key to
413 promote rural population stabilization and avoid land abandonment and the associated
414 risks it has such as the fires happened in 2006 in the Galician region with 100,000
415 hectares burnt in four days and two dead people or those happened in Portugal in 2017
416 with 40,000 hectares fired in three days with 64 dead people. Silvopasture, as a tool to
417 prevent forest fires, is key to reduce greenhouse gases emissions to the atmosphere,
418 therefore mitigating climate change (Schwartz et al. 2015). Mitigation and adaptation
419 activities are being promoted in the last decade at great extent in Europe mainly as a
420 consequence of the extreme events and the increasing awareness of climate change, but
421 there remains for large potential for future increase (Massey et al. 2014). Within the
422 CAP, silvopasture can be directly related with grazing practices promotion such as
423 forest grazing and mountain pastoralism. They were linked to forest lands and mostly
424 promoted by the agri-environment measure (50%) in both CAP periods studied,
425 therefore recognizing the important role that grazing has to preserve ecosystem services
426 such as biodiversity (Buttler et al. 2009). Grazing associated with permanent crops
427 (grazed orchards) in agricultural areas is also enhanced by RDPs and mostly by the agri-
428 environment measure (80% of the RDP). Grazing in permanent crops is of high
429 relevance to foster multiple use of the land in agricultural systems. The Pillar I of the
430 CAP never forbid the combination of these two agricultural activities in the same unit of
431 land. However, it is not extensively used in Europe (de Herder et al. 2017). Silvopasture
432 practices combined with fruit trees reduce clearing needs of the understory to diminish
433 competition between the herbaceous vegetation with the trees, therefore the
434 consumption of fuel of mechanical clearings. But it also brings other benefits, especially

435 in areas prone to be eroded as the soil herbaceous cover is maintained which also
436 contributes to increase the mitigation potential of these lands by the improvement of
437 organic soil carbon (Sánchez et al. 1995). Moreover, the grazing itself promotes nutrient
438 recycling as the animal consumes vegetation and transform it in nutrients for the tree
439 with their urine and faeces, reducing the needs of environmental costly fertilizers that
440 therefore mitigate also climate change. According to an Intergovernmental Panel on
441 Climate Change (2007) report, nitrogen fertilizers are the largest single source of
442 emissions from agriculture, accounting for 38%. The presence of livestock in permanent
443 croplands also enhance biodiversity thanks to the heterogeneity that animals cause
444 (faeces, vegetation selection by grazing and trampling) as described by Sánchez (1995),
445 Buttler et al (2009). The increase of biodiversity is connected with the increase of
446 carbon storage (Eitelberg et al 2016) and may be connected with a reduction of pests
447 and illnesses in the crops (Dupraz and Liagre 2011), therefore linked to a healthier food
448 production (Tscharntke et al. 2012).
449 Silvoarable practices (e.g. the combination of an arable crops with trees) only occupies
450 360,000 hectares representing less than 1% of the EU land occupied by agroforestry
451 practices, over half of it managed under permanent crops. However, silvoarable and
452 multipurpose or fruit tree silvoarable is only present in the 0.1% of its potential area,
453 similarly to USA (USDA 2013) with less than 1%. These values indicate that there is
454 huge potential for agroforestry practices to be expanded in the EU to mitigate and adapt
455 to climate change (Plieninger et al. 2011). The proportion of EU land allocated to
456 silvoarable practices is similar to that found in other temperate and developed countries
457 (USDA 2013). The reduced area of silvoarable practice in Europe is probably explained
458 because this practice is directly connected to arable lands. Arable lands were those more
459 affected by intensification, consolidation schemes to make plots bigger and the use of

460 machinery linked to ploughing to crop. Arable crops are usually more affected by shade
461 than grasslands (Pardini et al. 2010), as the latter have usually more biodiversity able to
462 adapt grassland production to different shade conditions. Moreover, intensification
463 practices related with seeding are usually connected to seeds that were selected to be
464 grown in open sites. It is for this reason why silvoarable practices are mostly linked to
465 woody vegetation that surrounds the arable land and less to isolated trees and forest
466 strips and small stands. Isolated trees, forest strips and small stands are supported by the
467 40% of the measures promoting agroforestry in agricultural lands in the two CAP
468 periods evaluated. The promotion of woody vegetation in arable lands through the
469 protection of isolated trees in forest strips and small stands is rather limited as they are
470 linked to losses of payments associated to Pillar I (Mosquera-Losada et al. 2016).
471 Riparian buffer strips and hedgerows are connected to both silvopasture and silvoarable
472 use of the land, but usually the promotion and preservation is linked to arable lands.
473 However due to the duration of the presence of the hedgerows, when considering
474 silvoarable and silvopasture as a plot land use, the time scale should be taken into
475 account as many plots are alternatively allocated to both silvopasture and silvoarable
476 practices (Moreno and Pulido 2009). This alternation of practices promotes biodiversity
477 preservation and better nutrient recycling, but it is difficult to quantify and to map them.
478 Hedgerows are the most extensively promoted activity in RDP linked to the inclusion
479 and preservation of woody vegetation and their role on biodiversity and mitigation and
480 adaptation to climate change mentioned by many authors. The importance of the
481 hedgerows to improve production and ecosystem services deliveries is the main reason
482 why DEFRA (1997) in UK protected them with national schemes since 1997 and the
483 reason behind Eastern European countries established networks of hedgerows across
484 countries (Kachova et al. 2016; Krcmarova et al. 2016). Moreover, the economical use

485 of these hedgerows may be increased in the forthcoming years, due to the use of
486 biomass as a source of renewable energy as it is currently promoted by EU countries
487 policies in forest lands (Ministerial Conference on the Protection of forests in Europe
488 2015).
489 Forest farming is mainly linked to forest lands and there are not available data to
490 identify neither to map the amount of land on which agricultural products are obtained.
491 This fact makes rather difficult to evaluate the impact of the different policies on them
492 mostly based in the amount of money that forest lands deliver without including the
493 social and cultural economic dimensions of forest farming. Naes et al. (2015) highlight
494 the role that small scale agroforestry projects may have on climate change policies. In
495 this regard, activities related to European LIFE or Interreg projects may be used as
496 piloting to innovate at field scale. However, the promotion of ecotourism and business
497 linked to processing NWFPs, the commercial utilization of the ecosystems services and
498 the facilitation of well-being and recreational values should be integrated (Ministerial
499 Conference on the Protection of Forests in Europe 2015a). This is because during the
500 Ministerial Conference on the Protection of Forests in Europe, it was also concluded
501 that the total value of market services for NWFPs is 723 million Euros with 49.8% for
502 social services (i.e. hunting and fishing licenses, renting of huts, sports), 25.0% for other
503 services (for example, licenses for farms, and gravel extraction), 21.2% for biospheric
504 services (i.e. carbon sequestration), 4.9% allocated to social services and 0.03% for
505 amenity services (those related to spiritual, cultural and historical functions). Indeed the
506 characterization of forest farming linked to forest lands is essential to adopt the best
507 policies to promote this activity with important social aspects such as rural population
508 stabilization, reducing of risk fires, increasing profitability from timber and not
509 products, etc. Apiculture is the most important forest farming activity enhanced by the

RDPs that also promoted activities linked to the market of the NWFP. Any of them will stabilize rural population thanks to the agricultural use of forest lands, therefore mitigating climate change through the reduction of forest fires and the promotion of short supply chains (Schwartz et al. 2015).

Homegardens are currently considered within the circular economy and the bioeconomy as a key tool to mitigate climate change. Activities linked to the increase of fruit trees and horticultural crop production in the surrounding areas of the cities will reduce the need of purchasing food from other countries and therefore the associated transport fuel expenditure, improving the balance of the greenhouse gases emissions (Tvinnereim et al. 2017). Homegardens are mainly associated with urban or peri-urban areas but also rural areas providing an excellent way of promoting local food as well as creating a link between cities and the countryside. This fits with circular and bioeconomy initiatives and is being promoted in cities like, for example, Gothenburg (Swedish National Agroforestry 2015). Activities related to permaculture, agroecology and also agroforestry as part of them (when the woody component is present) should be better enhanced to deliver more healthy foods as the biodiversity will be the baseline supporting these systems.

Policy support measures related with agroforestry are rather complex and extensive, which should be simplified. This complexity is justified because of the construction of the CAP on the previous ones and the successive evolution that CAP has, from a more productive approach to a more environmental friendly sustainable agriculture. Also, the increase of the number of countries involved in the CAP brought different socioeconomic and environmental contexts that should be considered. Finally, CAP used to have a plot based approach (mainly Pillar I) that may change to consider farm

and landscape approaches to improve the activities needed to fulfil the climate change challenges.

5. Conclusions

Agroforestry practices are spread all over Europe, but mainly associated to Southern European countries. Strong efforts should be carried out to establish agroforestry practices in Northern European countries but also to preserve them in Southern European countries. The methodology used is adequate as an indicator of the evolution of agroforestry practices at European level in the successive LUCAS survey, but stronger efforts should be done to characterize forest farming activities. CAP promotion of agroforestry practices is rather complex with over 25 measures scheduled to promote five agroforestry practices. Simplification of the measures should be carried out to directly connect payments to agroforestry practices and to allow the European Commission to follow up the agroforestry policy at European level.

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